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discharge tubes during the past ten years but that "it has been generally assumed that this helium has in some way been occluded in the bombarded material." True; we have a list of no less than 37 papers, most of them published in the years 1912 to 1915, engaged in this inconclusive argument. In spite of the application of the best experimental skill no agreement was reached and Rutherford's conclusion is the general one. Yet there are some of the final experiments, particularly those of Collie, which challenge that conclusion and the problem is still one of the most attractive and important of recent times. Certainly it urges conservatism and the most rigorous criticism, yet not one of the papers shows that helium can not be produced and all call for the application of some entirely new method to the same problem. That we have now accomplished.

The second point is that a measure of the energy produced by the atomic decomposition, as predicted by modern theories of atomic structure, would be "a much more definite and much more delicate test of disintegration of the heavy elements into helium than the spectroscope." This is a rare example of the preference for theory over fact, though saved by the use of the word "test" instead of "proof," and the chemist will be slow to accept it. Our work has not gone far enough to permit the measurement of the energy evolved but the latter is certainly not as large as would be expected from the energy liberated in the disintegration of radium. Yet lack of the theoretical energy does not explain away the formation of a cubic centimeter of permanent gas from half a milligram of tungsten wire, though it demands careful scrutiny and, if confirmed, some explanation. Perhaps a lesser energy content accompanies the greater stability of the permanent metals, for even among the radioactive elements the violence of disintegration varies inversely with the stability.

Finally Sir Ernest points out that no helium has been observed in X-ray tubes operating at 100,000 volts, where electron impacts are even more violent than in our experiments. But the quantity of energy impressed on the target is here minute, the tube current being measured in milliamperes or less, whereas it is the essence of our method to introduce as much as a coulomb of electricity into the wire within 1/300,000th of a second, or many millions of times as much in terms of power. We suppose that it is temperature as such, *i. e.*, the high velocity collisions of the atomic nuclei with one another, that effects the atomic decomposition.

We appreciate and welcome the spirit of Rutherford's criticisms. Indeed it is for the purpose of eliciting such criticism and stimulating the laboratory study by other investigators that we are publishing our work in its present preliminary form. The importance of the problem warrants it.

The real question now raised concerns the broadcasting of the results of scientific researches by our publicity agencies. This is an important function and science has suffered from its neglect. Yet our experience shows that it can be overdone, for here is a research heralded as "transmutation" to millions of newspaper readers in at least six countries: it is not transmutation in any proper meaning of that term, it is merely a preliminary report by no means accepted by, or offered to, the scientific world as conclusive, and it must still wait months before it can be properly published in the appropriate scientific journal for the study of those who are competent to appraise it. Meanwhile it is the duty of scientists to urge prudence and conservative judgment, as Sir Ernest Rutherford has done. Our publicity problems are not solved when we have increased the effectiveness of contact with the press.

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SCIENTIFIC LITERATURE

RECENT WORK ON SOIL ACIDITY AND PLANT DISTRIBUTION

WHEN three independent investigators, living in different countries, and not knowing of one another's activities, hit upon a similar method of study and reach essentially the same conclusions concerning a set of natural phenomena, it is not unreasonable to infer that a correct understanding of the relations has been reached. For many years it has been customary to regard soil acidity as having no particular bearing on the distribution of native

plants. The Danish ecologist Warming, it is true, distinguished a group of "oxylophytes"—acid place plants—but he had few followers. Coville[1] was successful in cultivating the wild blueberry and other *Ericaceæ* by maintaining the soil in an acid state, but this was looked upon by most botanists as anomalous and exceptional. Because supposed oxylophytes were occasionally found growing with supposed "calcicoles"—lime dwellers—ecologists in general have been inclined to discredit the existence of any definite relation between native plants and soil acidity. During the last few years, however, newly developed methods of interpreting and determining acidity have been applied in several widely separated regions—Sweden,[2] Denmark,[3] the northeastern United States,[4] (and subsequently in India and in England[5]), with the same result in all cases: recognition of the great significance of the acidity of the soil in controlling the growth and distribution of native plants.

The three investigators in question have found independently that the active acidity of a soil can be definitely determined by stirring up a sample with pure water and testing the extract with indicators adapted to show by their color changes the hydrogen-ion concentration. Arrhenius and the writer take their soil samples from the roots of the plants under study, while Olsen takes his at a uniform depth of 10 cm. His samples are therefore representative only of the plants rooting at that depth, and not of the shallower or deeper rooted ones. This renders his data as to some plants uncertain, since most soils show a marked acidity gradient, which may amount to as much as 0.1 p_H unit (equivalent to a factor of 1.25 in specific acidity) per centimeter in depth.

In a recent review, Clements[6] has shown that the production of acidity in bog soils is connected with lack of aeration; but it does not follow that the same is true of upland soils. In the writer's experience the highest acidities in them occur among rock fragments at the summits of mountains, in the dry sands of pine barrens, and in the most loosely packed and thoroughly aerated vegetable débris. This acidity is presumably due chiefly to the development in the soil of such acids as acetic, citric, and lactic, which, like their production for food purposes, is an aerobic oxidation process. In bogs, therefore, there is likely to be an increase of acidity with depth, in dry-land soils a decrease.

Before determining the acidity of a soil, Arrhenius and Olsen allow the water suspension to stand for as much as 24 hours, and then filter. The writer feels that long standing of a soil in contact with excess water may enable reactions, with resulting acidity changes, to take place which would not occur when the soil is in its natural condition, so that fairly prompt testing seems preferable. Moreover, filtration removes fine material which may well contribute to the effect of the soil on a plant, and therefore should be allowed to affect the indicators also. Arrhenius and Olsen make their determinations of the acidity of the modified and purified soil extracts with great precision, using a comparator, the former recommending, however, that a method of determination should always fit the sample. The writer, finding that the variation from one root to another of a single plant, or from one individual to another of the same species, often amounts to 0.5 p_H unit, or a factor of 3 in

1 "Experiments in Blueberry Culture," 1910, *United States Department of Agriculture Bureau of Plant Industry Bulletin No.* 193.

2 Olof Arrhenius: *Œcologische Studien in den Stockholmer Schaeren.* Stockholm, 1920. Review in *Ecology*, II, 223-228, 1921.

3 Carsten Olsen: *Studier over Jordbundens Brintionenkoncentration og dens Betydning for Vegetationen, saerlig for Plantefordelingen i Naturen.* Copenhagen, 1921. Abstract in SCIENCE, LIV, 539-541, 1921. English edition promised.

4 Edgar T. Wherry: A series of papers on ferns, orchids, Ericaceæ, etc. 1916 ——; also: "Soil Acidity and a Field Method for Its Measurement." *Ecology*, I, 160-173, 1920; to be published in collected form in the Appendix to the *Smithsonian Annual Report* for 1920. (In 1922).

5 W. R. G. Atkins: "Relation of the Hydrogen-ion Concentration of the Soil to Plant Distribution." *Nature*, CVIII, 80-81, 1921. Also *Sci. Proc. Royal Dublin Acad.*, XVI, 369-413, 1922.

6 "Aeration and Air-content; the Rôle of Oxygen in Root Activity." *Carnegie Institution of Washington Publ.*, 315, 183 pp., 1921.

specific acidity, developed his method so that it would yield just this degree of precision. These points are mentioned specially because Olsen, in the Danish paper, criticizes the writer's method severely on the basis of "inaccuracy." But if a soil, the acidity of which varies in general by a factor of 3, is sampled at an arbitrary depth and then altered by long soaking and filtration, there is certainly nothing to be gained by making highly precise acidity determinations on the resulting extract. Indeed, both Arrhenius and Olsen, upon assembling the results obtained on given species or associations of plants, also find that there is always a range of at least 0.5 in p_H (a factor of 3 in specific acidity). The fact that all three come to recognize the same range indicates that it is of fundamental significance.

All three investigators find that the soils of native plants in general extend from a specific acidity of a few thousand to a specific alkalinity of about 10. All find that the greatest number of species as well as of individuals occur in soils lying just to the acid side of the neutral point. And, most remarkable of all, it turns out that many individual species of plants have essentially the same soil acidity preferences in Europe as in America, indicating that this is not a question of location, climate, or surroundings, but a physiological feature of the species. For illustration: the lily-of-the-valley, *Convallaria majalis,* grows in Denmark in soils of specific acidity 1000 to 400. Isolated colonies of this plant in the southern Appalachian Mountains have been studied by the writer and found to have specific acidity 500 to 300, practically the same range. Hepatica (*Hepatica triloba* or *Anemone Hepatica*) shows in Denmark preference for soils ranging from neutral (specific alkalinity 1) to specific alkalinity 8. In America a near relative of the European plant thrives best in black leafmold with an average specific alkalinity of 3.

How soil acidity affects plants is a subject requiring further investigation. Olsen's data led him to infer that the action may be direct, but others have found that it is usually indirect. There is evidence both for and against the view that the acidity affects primarily symbiotic organisms, and only indirectly through them the higher plants. Recent American work has indicated that the effect of acidity is produced largely through the agency of aluminium or iron salts, although Olsen is unable to find evidence of their toxicity. But in view of the general agreement of the results of the three independent investigators as above outlined, it can no longer be questioned that soil acidity is of fundamental importance in controlling the distribution of native plants.

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SPECIAL ARTICLES

THE EINSTEIN EQUATIONS FOR THE SOLAR FIELD FROM THE NEWTONIAN POINT OF VIEW

1. About a year ago I determined the law of attraction from the Newtonian point of view of action at a distance which gives the equations of planetary motion obtained in the Einstein theory. Two months ago Professor Birkhoff, of Harvard, told me that he had obtained similar results in his class this year, and suggested that I publish my results. In doing so I am not advocating the rejection of the Einstein point of view which seems to me the correct one, but I am merely indicating a modification in the Newtonian law which will account for the motion of the perihelion of Mercury and the deflection of light rays. It may be also that by means of this formulation of the law it will be possible to solve, with sufficient accuracy, problems which are not readily handled by means of the equations of general relativity.

2. The Schwarzschild form of the linear element of the Einstein field of gravitation of a mass m at rest with respect to the space-time frame of reference is

$$(1)\ ds^2 = \left(1-\frac{2m}{r}\right)dt^2 - \frac{1}{1-\frac{2m}{r}}dr^2 - r^2(d\theta^2+\sin^2\theta d\varphi^2)$$

where r, θ and φ are the space coordinates as measured by astronomers, and t is the coordinate of time.